MI SBD Specifications

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DRAFT
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Abstract:

In this report we present the MI SBD specifications and requirements for the Run II, NuMI and SY120 operation of the MI from now till ~2010 for longitudinal emittance measurements. Various modes of operation of the MI during this time are outlined in two tables with expected properties of the beam (cycle type, rep. rate, beam intensities, bunch length, bunch structure and energy range of the MI etc.). The SBD modes presently being used are also shown. Some typical cases of wall current monitor data and schematic view of various MI cycles of interests are displayed. We also give algorithm to be used in the emittance calculations.

What are MISBD mode files?

Mode file is an input parameter list for MISBD system which uniquely defines a particular mode of operation of MI.

1.	Title	2A&9A pbar Emittance Measurement
2.	Mode Number	17
3.	Injection Frequency(kHz)	89.815
4.	Harmonic Number	588
5.	Transition Energy	20.488
6.	TclkReset	2A
7.	TclkTrigger	9A
8.	#of Batches	4
9.	# of Acquisitions (Range 1-24)	**3**
10.	Starting Time (sec)	4.3
11.	Delta t	0.0
12.	Giga Samples/sec	4
13.	Gain	0.05
14.	Starting Sample	055
15.	First Displayed Bucket	0
16.	# of displayed buckets	84
17.	TV display control	1
18.	1st call	-1
19.	Injection Momentum	8.8889
20.	Bunches /batch	21
21.	Spare 1	
22.	Spare 2	
23.	Spare 3	
24.	Spare 4	

This combination tells the SBD system to take traces 1+3 times. First time the trace will be taken at 4.3sec after 2A and next three times traces will be taken at I:SBDTIM[1],I:SBDTIM[2] and I:SBDTIM[3] set by user by this mode table.

SBD Modes: Collider Operation

Operational

Description of the Cycle	Beam (cycl. Time)	Bunch Type	Mode #	Energy Range (GeV)	Intensity Range	Expected Min.rms-width (nsec)	Applications **
Pbar Stacking $29 +1F, # of Bunches = 84	P (1.47s)	53MHz	4	8-120	1-10 $\times 10^{12}$	≈ 0.25 (@ tran.)	Stacking efficiency SDA
Protons to Tevatron $2B+15, # of Bunches = 5-7	p (3.5s)	53MHz	19	8-150	0.2-0.6 $\times 10^{12}$	≈ 0.25 (@ tran.)	Ppbar Luminosity SDA
AR Pbars to Tevatron $2A+9A, # of Bunches = 4	Pbars (8 s)	2.5MHz @ inj. 53MHz @Ext.	17	8-150	5-50$\times 10^{10}$	≈0.25 (@ tran.)	Ppbar Luminosity SDA
RR Pbars to Tevatron $2A+E4, # of Bunches = 4	Pbars (8 s)	2.5MHz @ inj. 53MHz @Ext.	18	8-150	5-100$\times 10^{10}$	≈ 0.25 (@ tran.)	Ppbar Luminosity SDA
AR Pbars to RR $2D+E0, # of Bunches = 4	Pbars (5 s)	2.5MHz	16	8	5-100$\times 10^{10}$	≈ 12	RR-pbar stacking efficiency, SDA
RR Pbars to MI to RR $2D+E4, # of Bunches=4	Pbars (5 s)	2.5MHz	??	8	5$\times 10^{10}$	≈ 12	Round trip efficiency SDA

Study/Development

RR Pbars to Tev., 2.5MHz Accel.* $20+E4, # of Bunches = 4	Pbars (13 s)	2.5MHz @ inj. 53MHz @Ext.	15	8-150	4-100$\times 10^{10}$	≈ 2	Ppbar Luminosity SDA
Proton, 2.5MHz Accel. $20+1C, # of Bunches = 4	p (13 s)	2.5MHz @ inj. 53MHz @Ext.	14	8-150	5-100$\times 10^{10}$	≈ 2	Acceleration Tuning
Protons to RR $2D+1C, # of Bunches = 4	p (5 s)	2.5MHz @ inj.	12	8	5-100$\times 10^{10}$	≈ 12	RR Tuning

* The cycle combinations will be changed from $20+XXX to $2A+ XXX once it is made operational

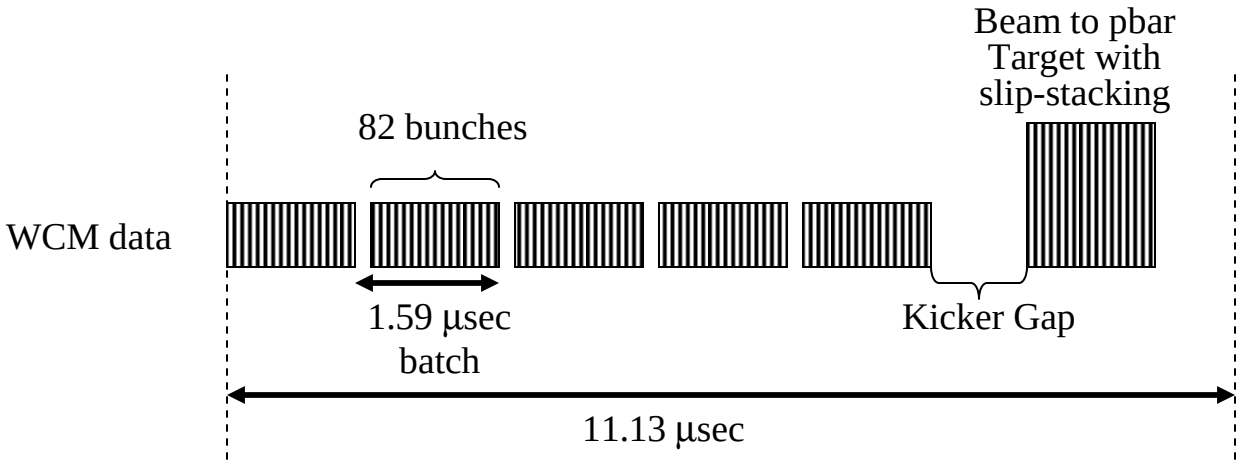
** The expected "Min rms width" will not be used in the final applications. But the Min rms width will be used for establishing the SBD specifications

SBD Modes: Fixed Target Experiments

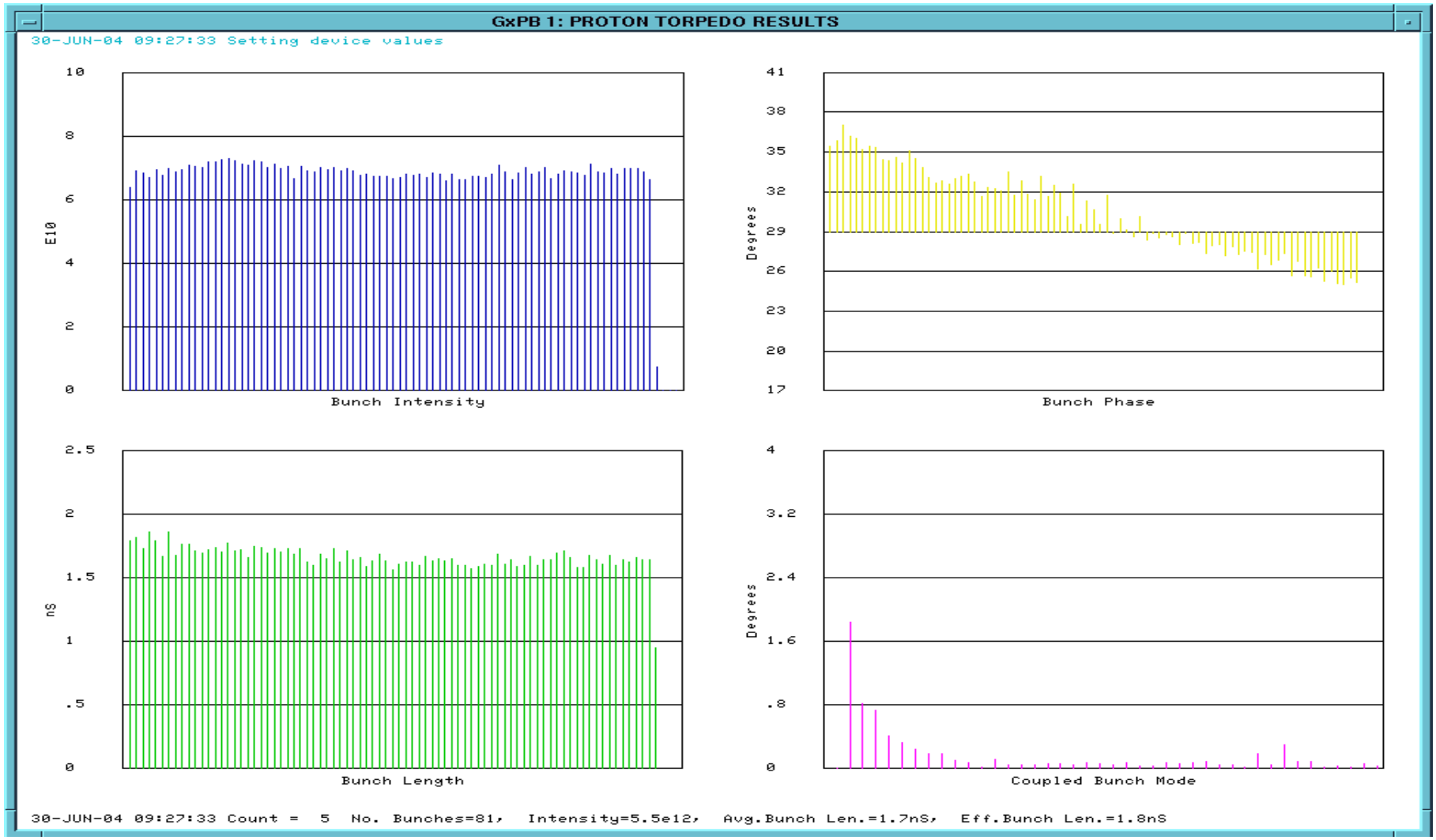
Description of the Cycle	Beam	Bunch Type	Mode #	Energy Range (GeV)	Intensity Range	Expected Min.rms-width (nsec)	Applications *
NuMI $23 +19, # of Bunches = 82×6	P (1.9s)	53MHz	??	8-120	1-4×10^{13}	≈ 0.25 (@ tran.)	Stacking efficiency
Pbar Stacking +NuMI (Mixed mode) $23 +19, # of Bunches = 82×6	p (~2s)	53MHz	??	8-120	1-5 (??)×10^{13}	≈ 0.25 (@ tran.)	Stacking efficiency and quality of the beam on NuMI target
Pbar Stacking + SY (Mixed Mode) $21 +13, # of Bunches = 82×6	p (~3s)	53MHz	??	8-120	1-10 ×10^{12}	≈0.25 (@ tran.)	Stacking efficiency

* The expected "Min rms width" will not be used in the final applications. But the Min rms width will be used for establishing the SBD specifications

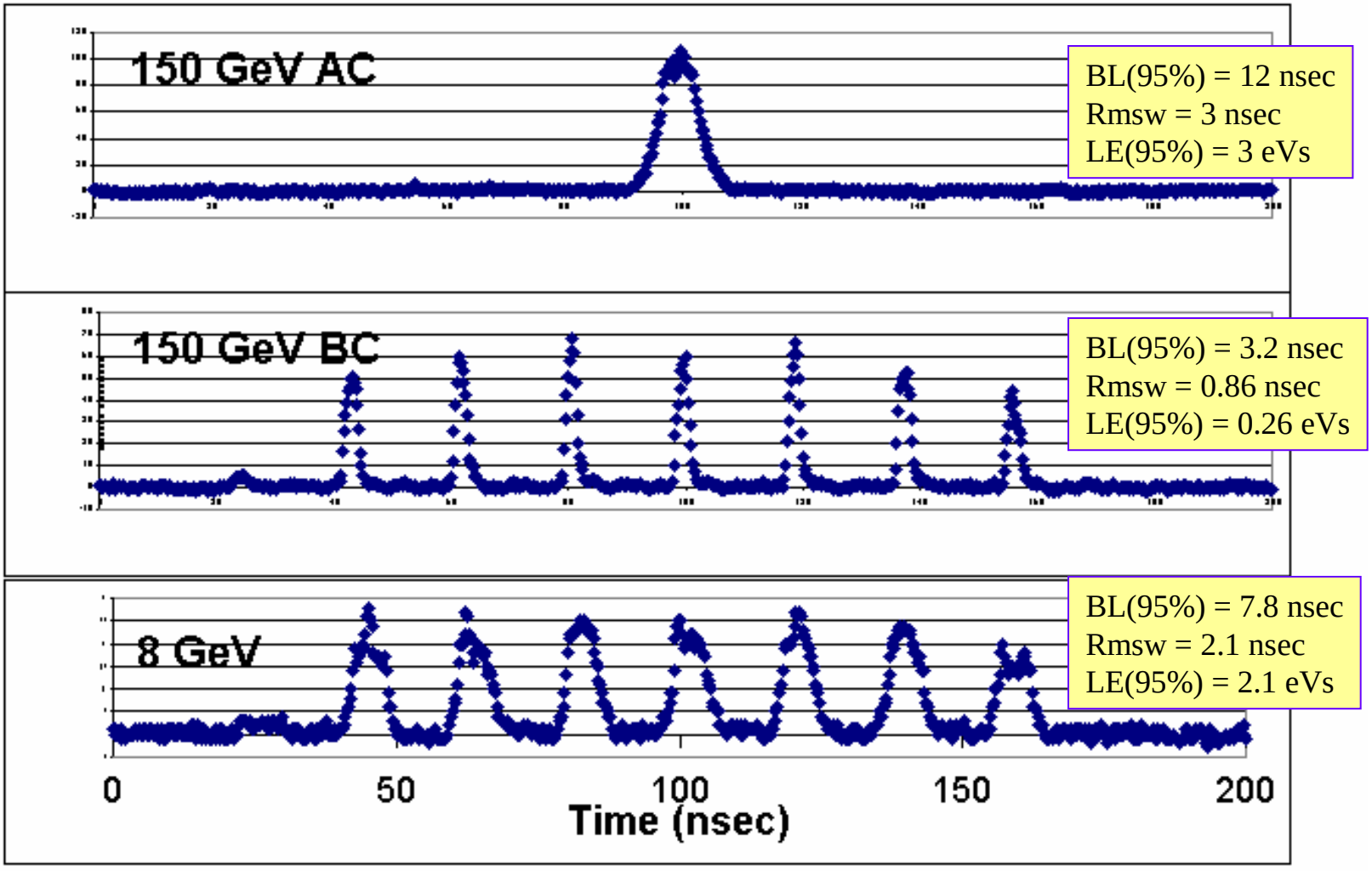
Schematic View of the Bunch Traces during Mixed Mode Operation:



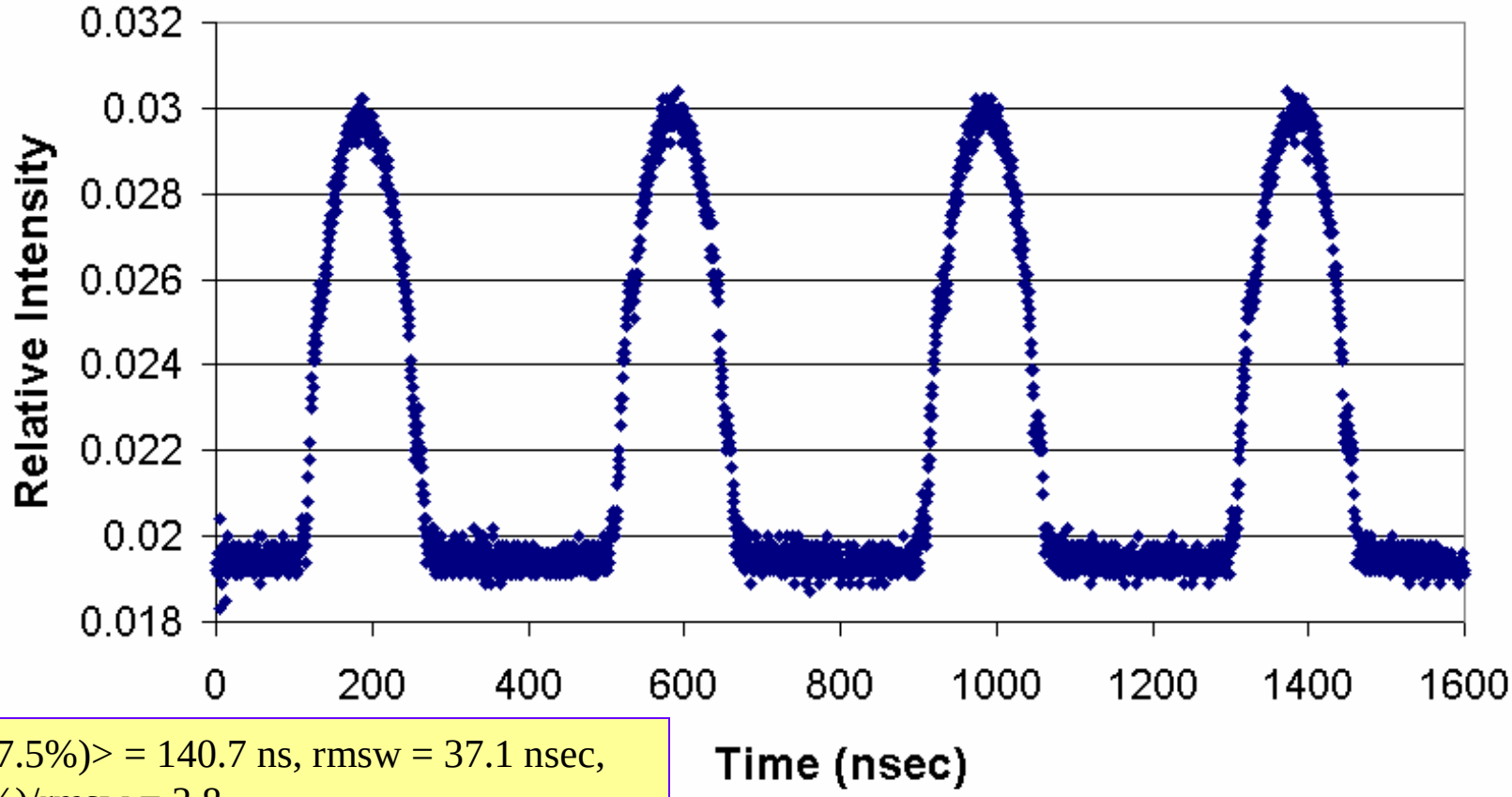
Sample of Proton torpedo display in the pbar beam-line



Sample of Proton bunches to Tevatron: 53MHz Bunches

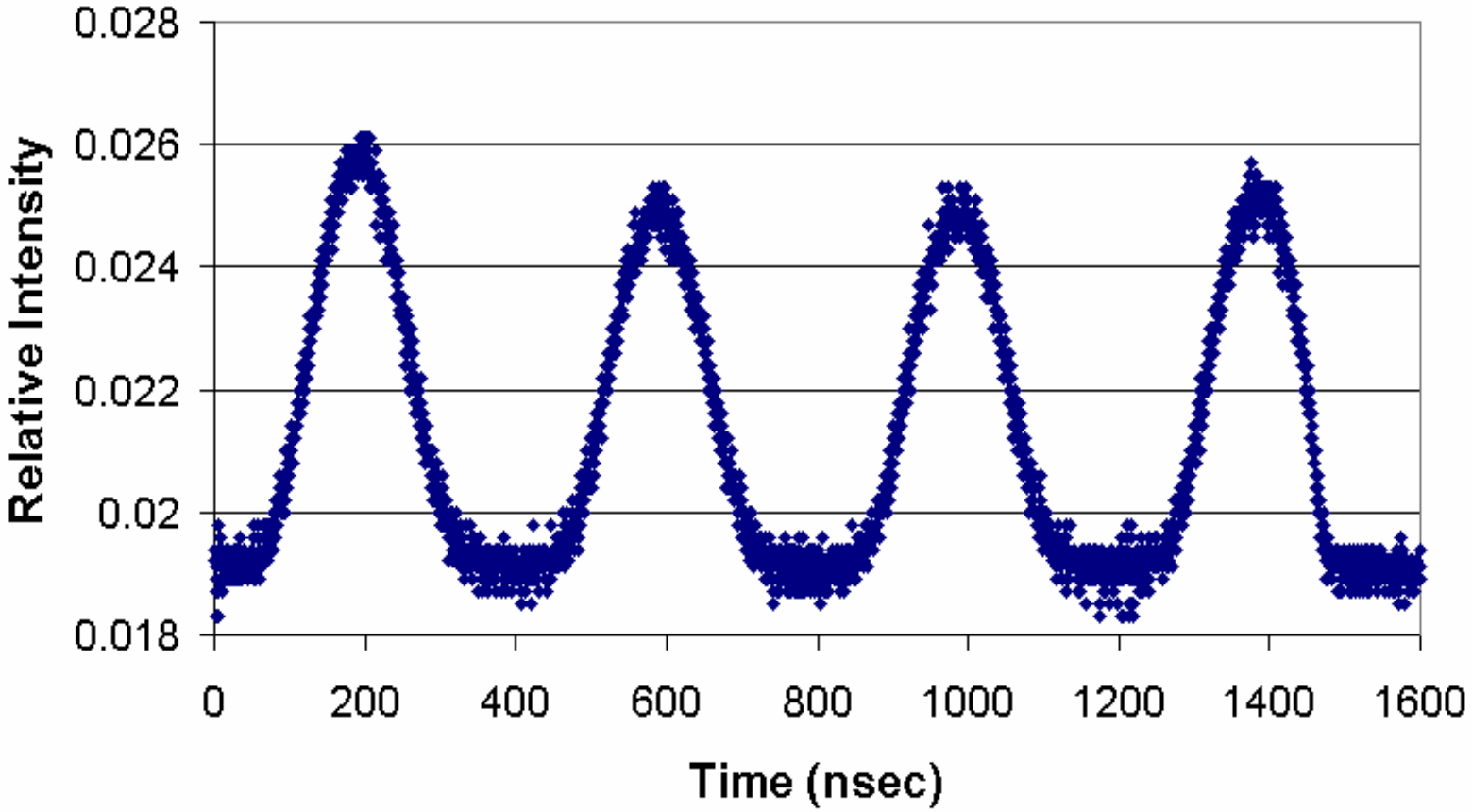


2.5MHz pbar Bunches at 8 GeV
AR to MI



<BL (97.5%)> = 140.7 ns, rmsw = 37.1 nsec,
BL(95%)/rmsw = 3.8
<LE(95%)> = 0.66 eVs
Meas. At MI<LE (full)> = 0.83 eVs (fit)
Meas. At AR<LE (full)> = 0.82 eVs (fit)

2.5MHz pbar Bunches at 8 GeV
RR to MI



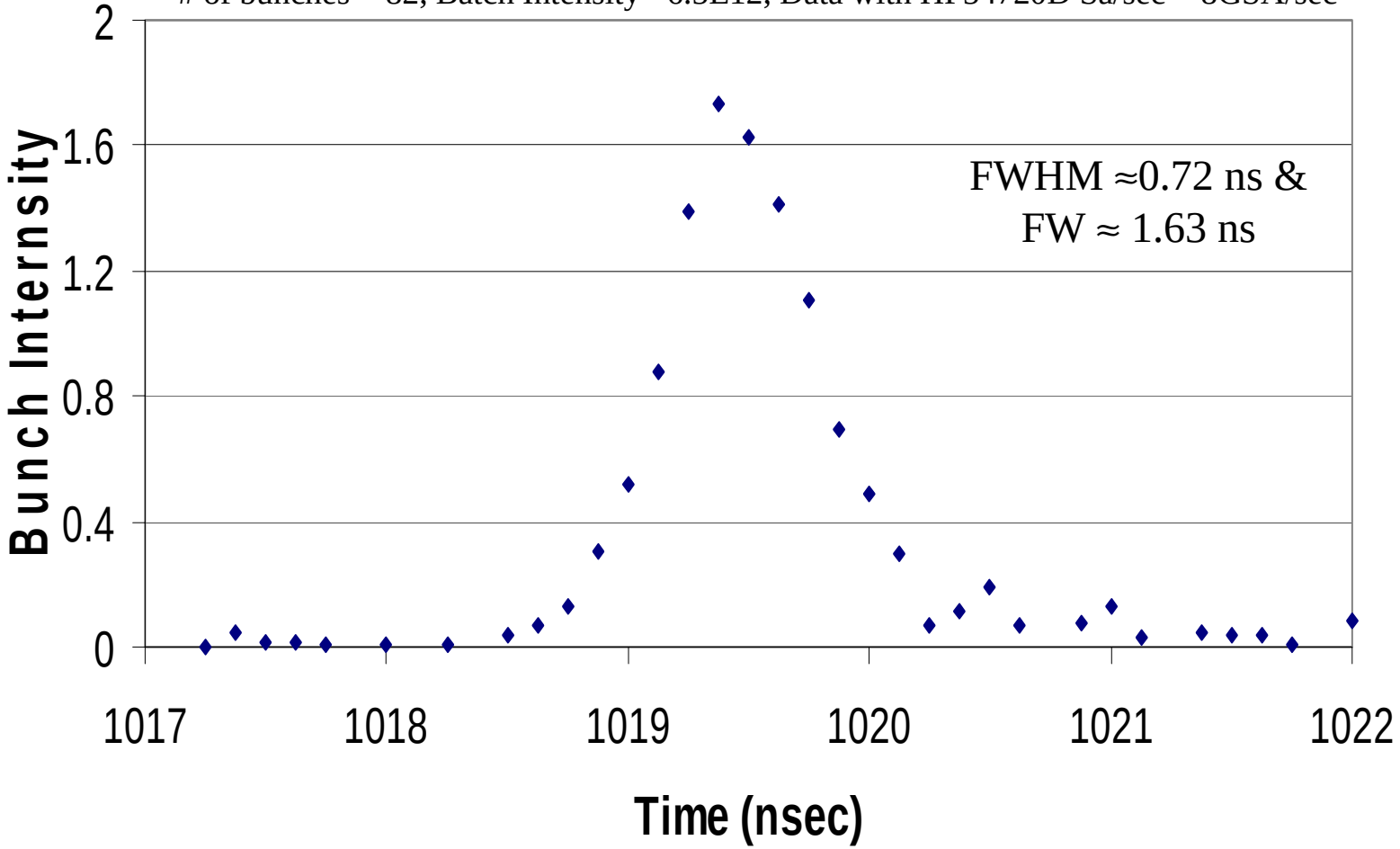
<BL (97.5%)> = 214.2 ns, <rmsw> = 51.3 nsec,
BL(95%)/rmsw = 4.18
<LE(95%)> = 2 eVs

Typical case of a bunch at 120 GeV

Beam with slip stacking after bunch rotation

Data from Kiyomi Seiya (October, 6 2004)

# of bunches = 82, Batch Intensity ~6.5E12, Data with HP54720D Sa/sec = 8GSA/sec



Algorithms for Longitudinal Emittance

Longitudinal Emittance in eVs

$$\varepsilon_l = 121.733\sqrt{\frac{\gamma V_{rf}(MV)}{|\eta|h^3}}\int_0^Q \sqrt{\cos(x)-\cos(Q)}dx$$

where Q is half bunch length in radian

$$Q = \pi\left(Bunch\ \ Length\,(ns)/\tau\right)$$

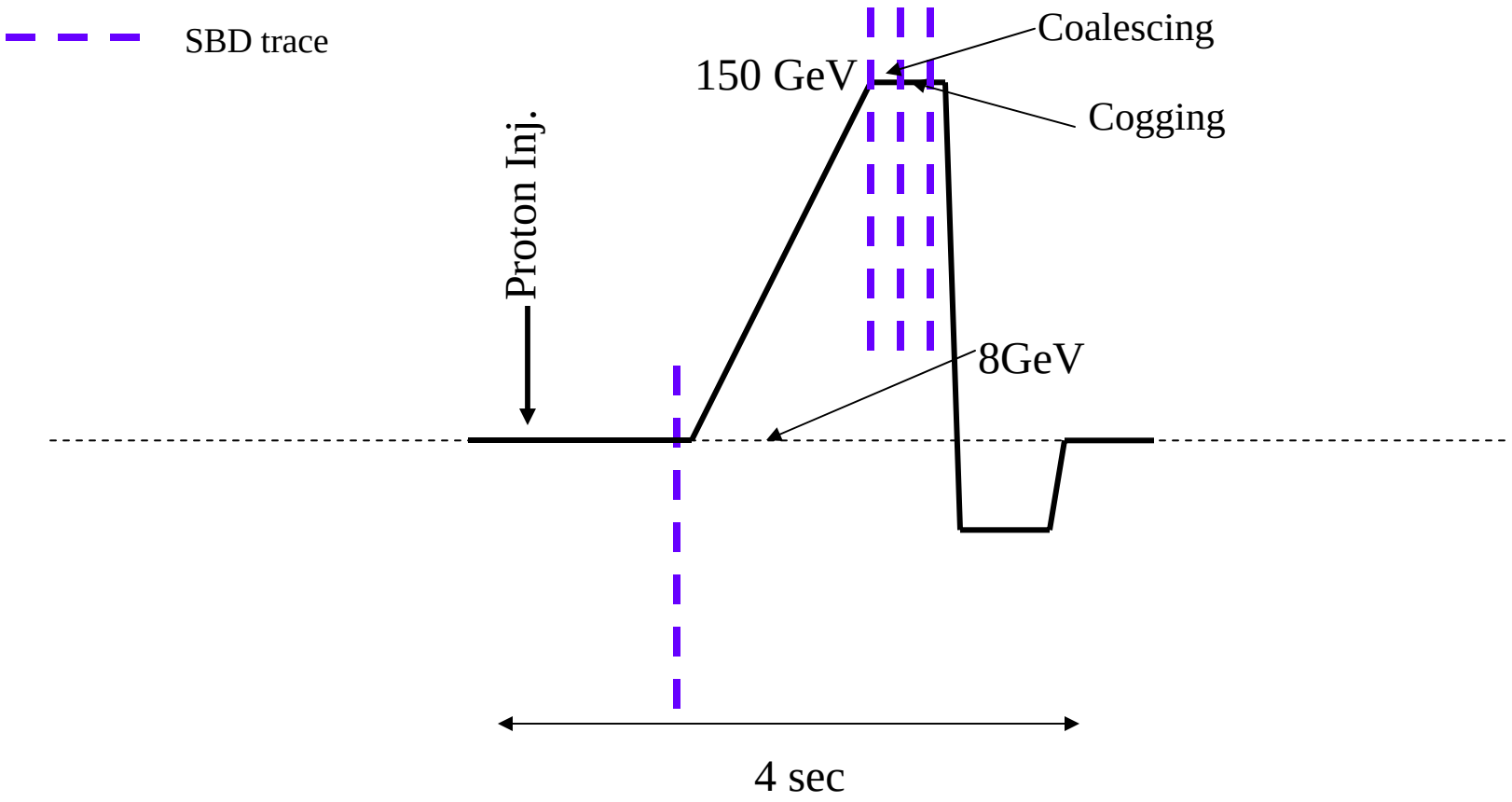
$$\tau = \frac{\mathrm{Re}\,volution\ \ Period\ (n\,\mathrm{sec})}{h}$$

$$Bunch\ Length = C\left\langle RMSW\right\rangle; C = 4,$$ a better value will be set later

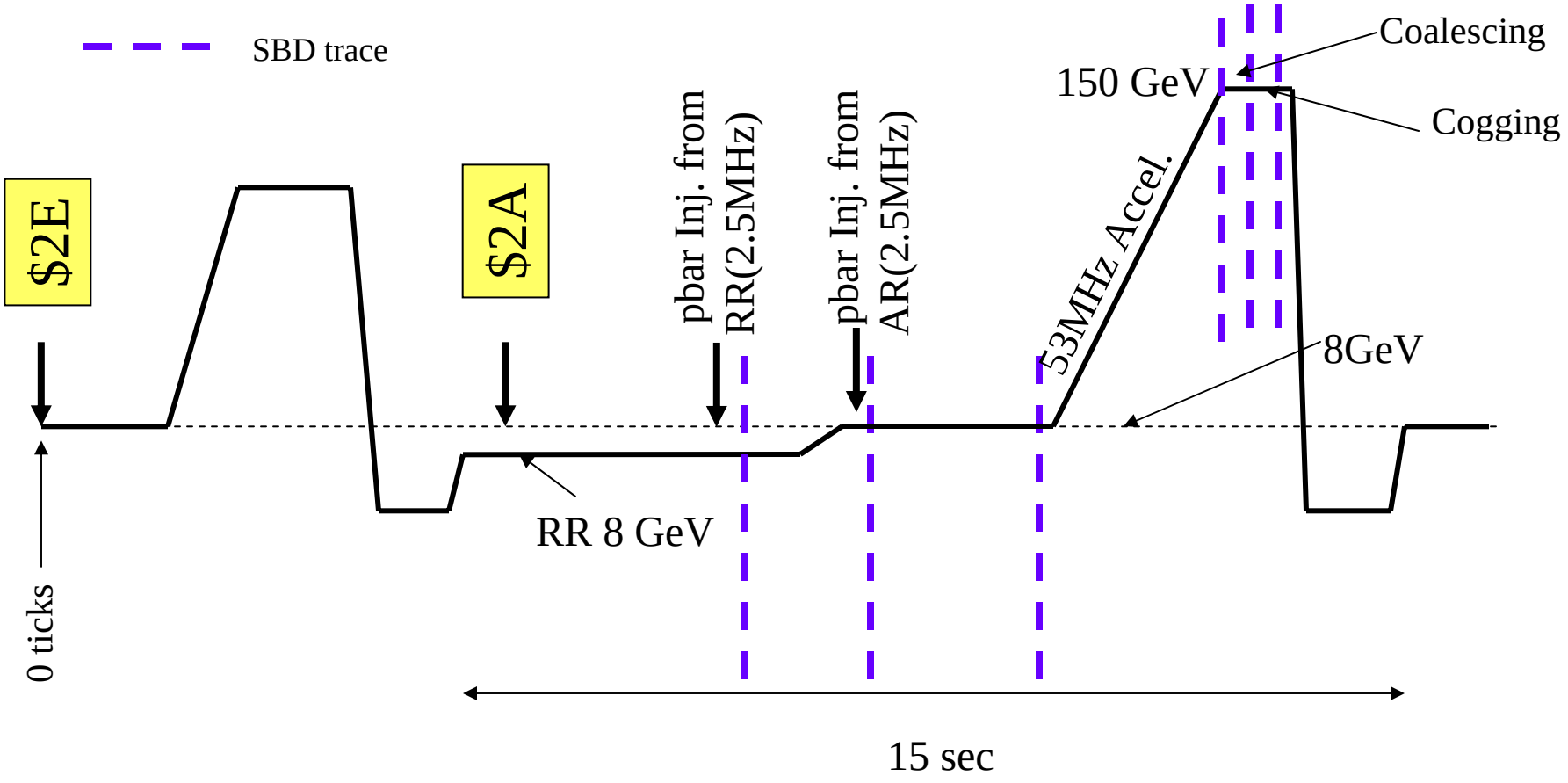
$$\frac{dp}{p}(\%) = \pm 2.604\sqrt{\frac{V_{rf}(MV)}{|\eta|h\beta^2\gamma}}Sin\left(\frac{Q}{2}\right)$$

h = 28 for 2.5MHz rf bunches and h=588 for 53MHz bunches

MI cycle: Booster Protons to Tevatron, 53 MHz Acceleration

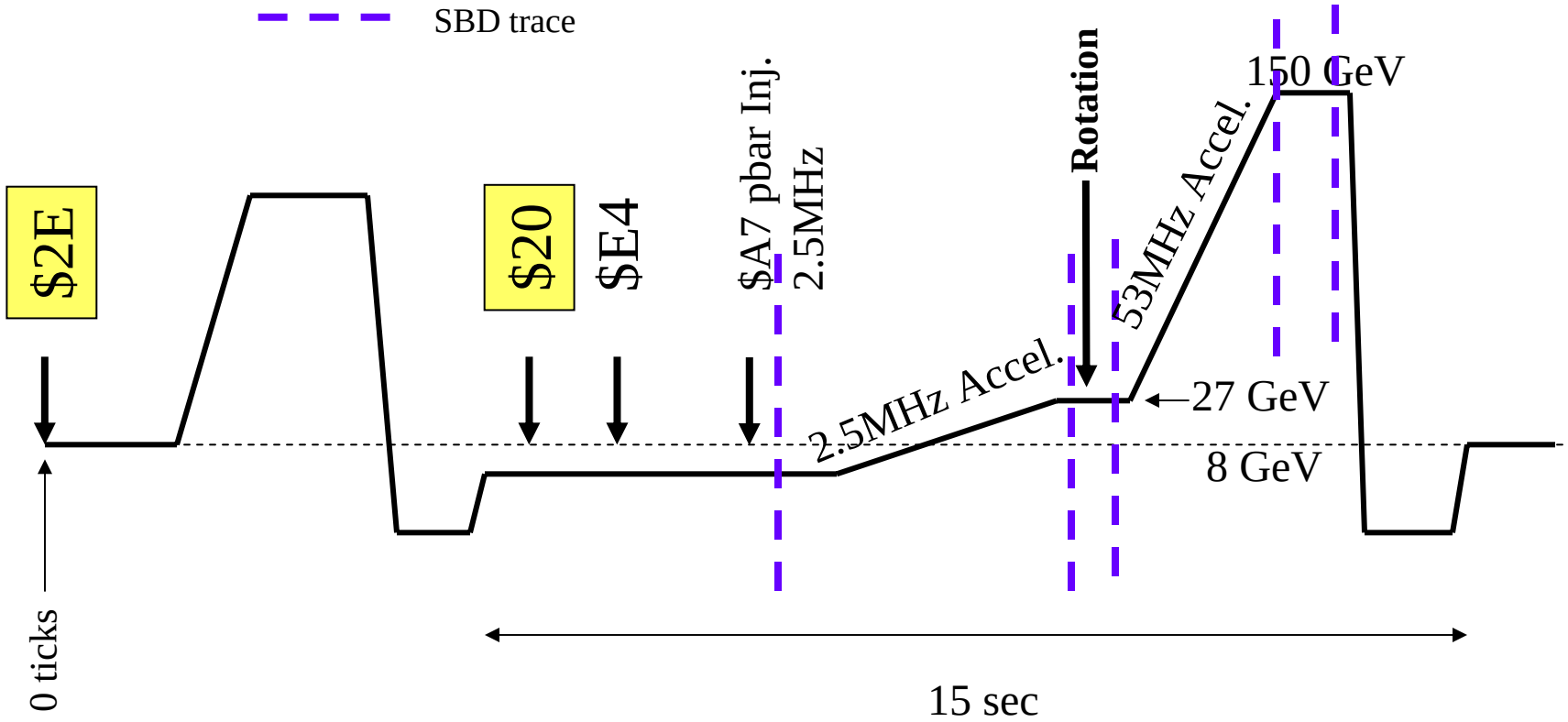


MI cycle: AR/RR Pbar to Tevatron, 2.5MHz pbar injection and 53MHz Aceleration



Need SBD at these points in the cycle

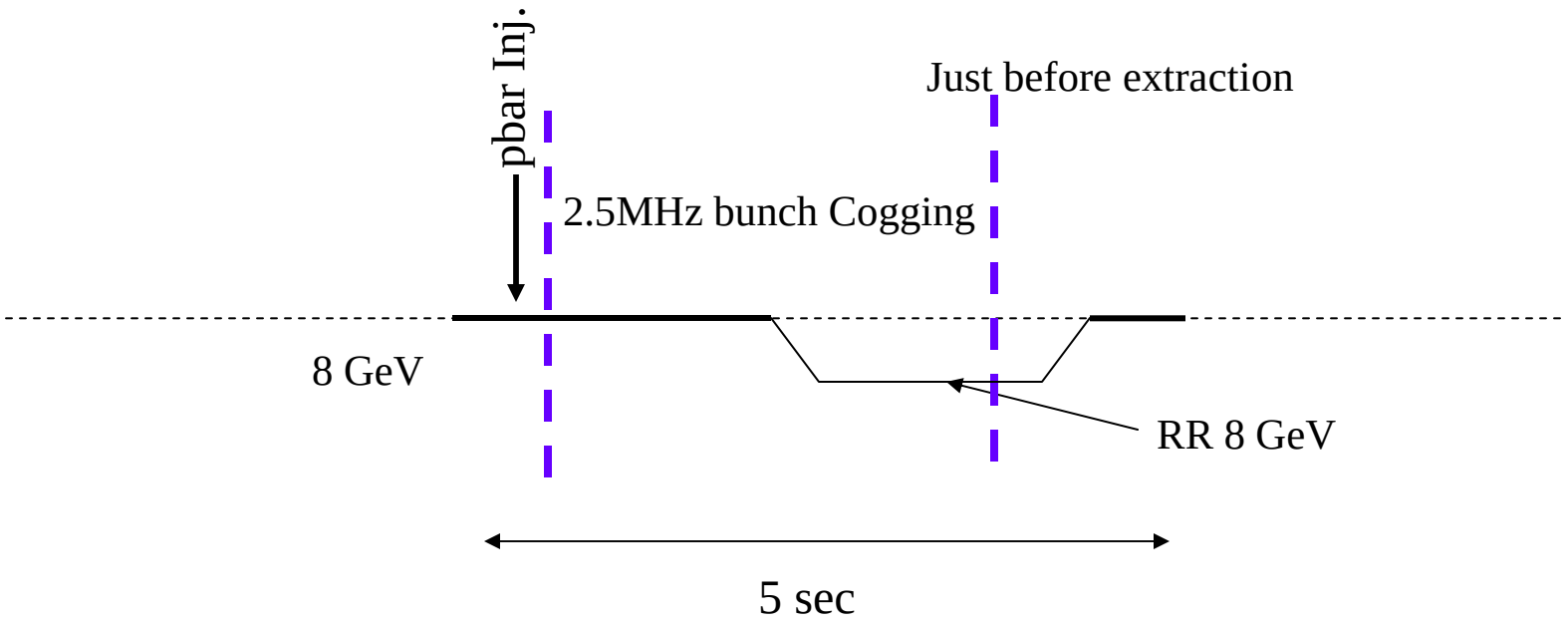
MI cycle: RR Pbar Acceleration from 8-27 GeV with 2.5MHz +27-150 GeV with 53MHz systems



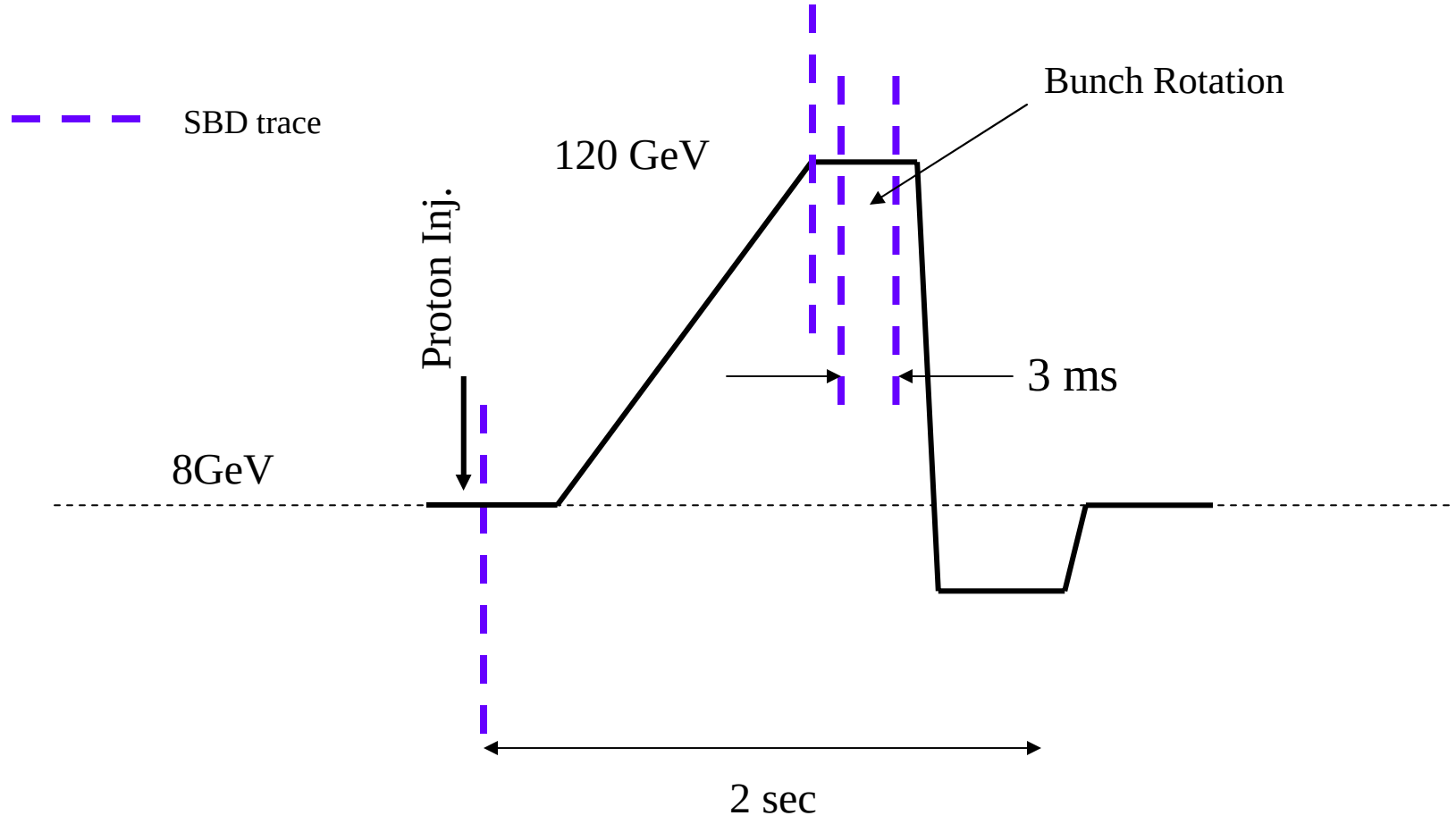
Need SBD at these points in the cycle

MI cycle: Pbars to RR

SBD trace



MI cycle: Protons for Pbar Stacking and NuMI or SY120 experiments



MI SBD Specifications and Requirements

- **Collider Operation:**
  - **RMS Bunch length measurements:** 0.4 – 100 nsec with an accuracy of ±10%
  - Longitudinal Emittance (with an error < ± 20%. Use measured Vrf and bunch length):

    Measure up to 5 different timings in the cycle for collider operation both for protons and pbars and, be able to store in SDA

    Pbars:

    a) On pbar cycles, we need emittance of the beam in 2.5 MHz buckets at injection and with 2.5 MHz pbar acceleration scheme in use, we need emittance of the beam in 2.5MHz buckets at 8 and 27 GeV.

    b) During 53MHz acceleration, we need longitudinal emittance measurements at the beginning and at up to 3 different points at 150 GeV for the present mode of operation.

    Protons:

    Be able to measure long. emittance at 8 GeV, and at four different points up the ramp.
  - **Bunch Intensity (better than 2% with respect to the DCCT measurements):**

    (a) for 53MHz bunches on proton cycles

    (b) for pbars in 2.5MHz and 53MHz buckets on the pbar cycles.

    (c) Be able to store in SDA.
  - **TV Display of Raw data for protons and pbars (just like now or with improved display) and web-display for the individual to monitor from their offices.**

MI SBD Specifications and Requirements (cont.)

- Pbar stacking, Beam to NuMI and SY120 cycles (mixed mode and unmixed mode operation)
  - **RMS Bunch length measurements:** ≈0.4 nsec with an accuracy of ±10%.
  - **TV display (torpedo display):** Measured RMS bunch lengths, Bunch intensities and Bunch phases for all 588 bunches and, Coupled bunch mode display.

    (a) Data should be displayed at 8 GeV injection,

    (b) at flat top,

    (c) before proton transfer to pbar target (after bunch rotation) and

    (d) before proton beam extraction to NuMI target.

    Note that trigger gap between (c) and (d) is about 2 msec.

    These will used for online beam diagnostic for every cycle of this type.
  - **Datalog**

    a) batch by batch average RMS bunch lengths,

    b) batch by batch average bunch intensities, (intensities better than 2% with respect to the DCCT measurements).
  - **TV Display Raw data for protons (just like now or with improved program) and web-display for the individual to monitor from their offices**.
- **Ability for raw data collection for off-line data analysis.**

What problem could arise if the base line is not corrected properly?